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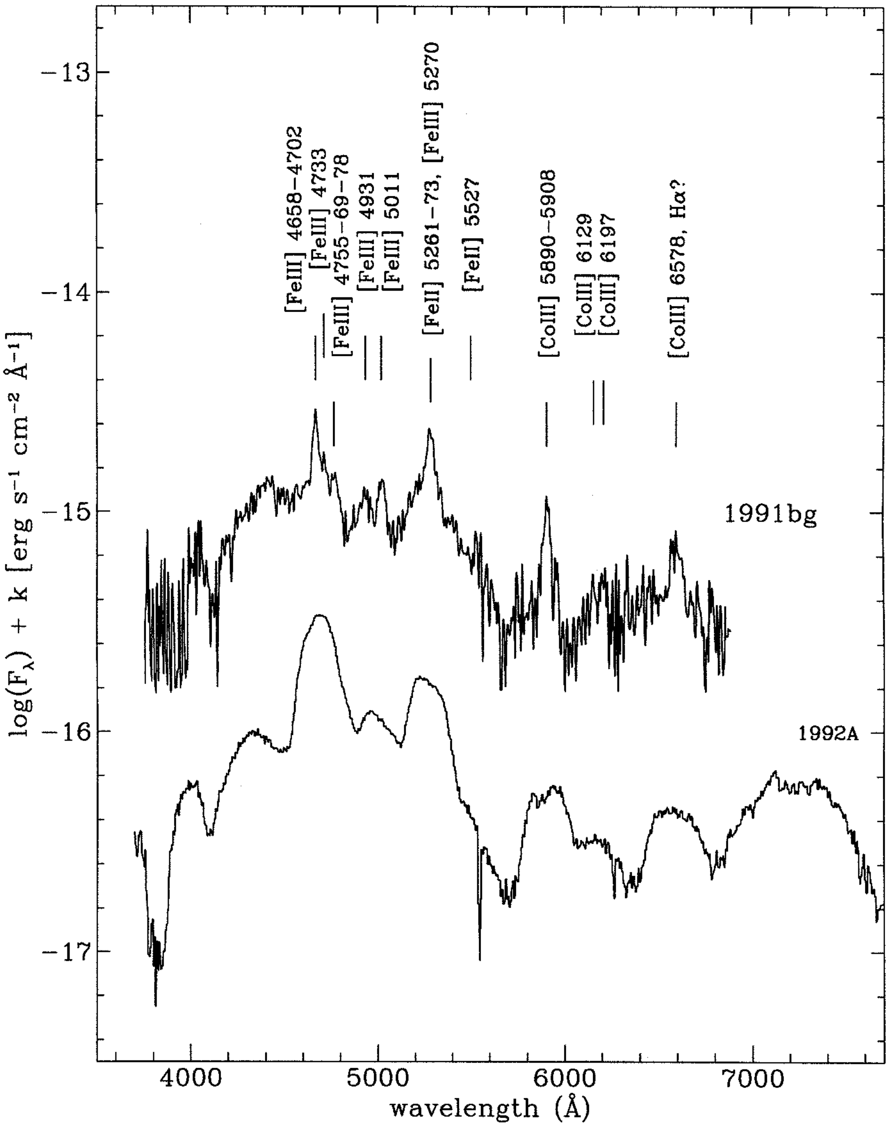

Figure 3: Comparison of the late spectra of SNe 1991bg (203 days) and 1992A (227 days), both obtained with EFOSC1 at the 3.6-m telescope. The identifications of the main emission lines are based on the NLTE models by Mazzali et al. (1996).

Long-Slit Echelle Spectroscopy at the NTT

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During our recent observing run at La Silla (April 26–28, 1996), we had the chance to experiment successfully a previously unexplored capability of the NTT: high-dispersion spectroscopy using the full slit length of EMMI.

The EMMI-REMD (REd Medium Dispersion) spectroscopic mode is provided with three echelle gratings (#9, #10, and #14), which give spectral resolving powers of 7700, 28,000, and 60,000, respectively, for a slit width of 1″ and the actual Tek 2048 × 2048 CCD #36. These gratings are normally coupled to a grism which acts as a cross-disperser to obtain conventional multi-order echelle spectroscopy. The closeness of adjacent orders, while providing a large total spectral coverage, limits the usable slit length to a few arcseconds. For several astrophysical applications, however, it would be highly desirable to have a longer slit. This can be obtained by taking off the cross-disperser, and isolating one echelle order by means of a narrowband filter mounted in the filter wheel unit (see the *ESO Operating Manual* No. 15, Zijlstra et al., 1996, for more details). In this way, one can take advantage of the full length of the EMMI-REMD slit (6 arcmin!), and work at very high spectral and spatial resolutions (R ≤ 70000, with a spatial scale of 0.27″ pix^{-1}, matching excellent seeing conditions which are not infrequent at the NTT).

With this configuration, the spectral coverage is of course limited to few manometers by the width of the narrowband filter, and normally includes one or few spectral features. It is, however, a very powerful combination for many applications which concern the observation of extended objects with narrow spectral features, such as Galactic HII nebulae, and possibly external galaxies.

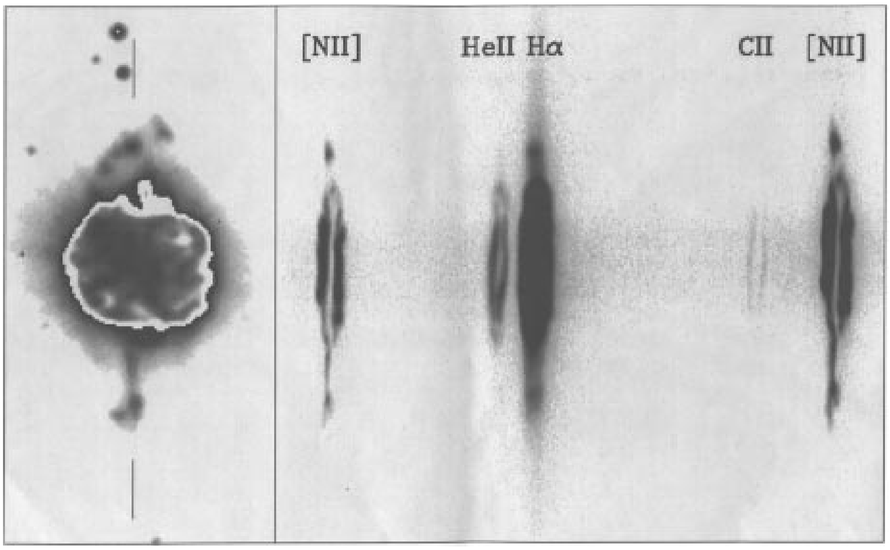

Figure 1. To the left, a [NII] image of the planetary nebula NGC 3918, rotated in order to have the adopted slit position (indicated by short lines on either side of the object) aligned with the vertical direction. Different intensity cuts have been used for the inner and outer part of the nebula. Intensity levels are on a logarithmic scale. The total extension of the figure in the vertical direction is 1 arcmin. On the same spatial scale, in order to facilitate comparison with the image, we present to the right the raw long-slit echelle spectrum of the object. The spectral region from 654.5 to 658.7 nm is displayed, corresponding to about 1000 pixels.

A limitation of this observing mode is the relatively small number of narrow-band filters available at EMMI, which however include the following important spectral features in the study of emission-line regions: He I at λ 447.1 nm, He II 468.6, Hβ, [O III]500.7, Hα, [N II]654.8,658.3, [S II]671.6,673.1, and [S III]953.2. Some simple test should however be done in order to check if all these filters have a suitable FWHM to isolate the selected spectral range without overlapping with neighbouring orders. Another problem to be taken into account is that the filter efficiency at a given wavelength changes along the slit. This limits the accuracy of relative flux calibration along the slit, but it should not be too serious for relatively broad filters.

A rapid excursion to other European observatories shows that long-slit echelle spectroscopy can be performed at the ORM Observatory in the Canary Islands (using the 4-m WHT telescope +UES spectrograph or the 2.6-m NOT+IACUB), as well as at the Anglo-Australian Observatory (4-m AAT+ UCLES). At ESO, the 3.6-m+CASPEC is also provided with a similar capability. None of these instrumentations, apart from IACUB at the NOT, can however provide the spatial resolution of the NTT, and in any case none of them have such a remarkably long slit. In addition, and unlike the above-mentioned instrumentations, EMMI can be switched from the high-resolution spectroscopy mode to imaging or low-dispersion spectroscopy in a short time. This is very useful, for instance, for precise positioning of the target into the slit. These properties make the NTT+EMMI a unique instrument of this kind.

Our run at the NTT of past April was part of a programme aimed at investigating the nature of low-ionisation microstructures in planetary nebulae (PNe). Extensive imaging surveys of PNe (e.g. Schwarz et al. 1992) fully illustrate the bewildering variety of shapes that characterises this class of objects. Besides the presence of typical large-scale components (cores, shells, halos, bipolar lobes), PNe show very interesting microstructures which are enhanced in the light of low-ionisation species such as [N II], [S II], or [O I]. Some of these small-scale structures have been studied in detail by Balick and collaborators (1993, 1994), and found to be one of the most puzzling components of PNe. They usually appear in the shape of radially symmetrical pairs of knots, ansae or filaments, move supersonically through the ambient gas, and are nitrogen (only) enriched. None of the models presently available can fully account for their observed properties or can even explain their existence. We have recently identified (Corradi et al., 1996) several new candidates of this kind in 23 PNe, by using the emission-line images of Schwarz et al. (1992), and dividing the Hα+[N II] frames by the [O III] ones. In the ratio maps, these ionisation features stand out clearly.

In an attempt to understand these structures, the basic piece of information is the detailed kinematics of the nebulae. As typical expansion velocities of planetary nebulae range between 10 and 30 km s^{-1}, a high spectral resolution is required in order to resolve their various kinematical components. For the purposes of our project, the possibility of obtaining long-slit spectra at R ~ 60,000 is therefore a very appealing one. For this reason, during the first afternoon of our observing run, we made a quick test and decided to carry on our programme with the following configuration: EMMI-REMD mode with the echelle grating #14 plus the "broad" Hα filter ESO #596, whose central wavelength and FWHM are of 656.8 and 7.3 nm, respectively. This combination isolates the spectral region containing the nebular emission lines of Hα and both the [N II]654.8,658.3 collisionally excited lines. Some contamination from the same spectral lines from an adjacent order is present but does not overlap with the region of interest. Note that, having removed the cross-disperser, the spectrum appears as a conventional grating long-slit spectrum (which in fact is), with the spatial and spectral directions perpendicular to each other (apart from the usual slit distortions) as opposite to the characteristic inclined echelle multi-order spectra.

An example of a real exposure obtained during our observations is presented in Figure 1. This is a median average of three 10-min spectra of the PN NGC 3918, whose [N II] image is also presented in the left side of the figure. The slit was positioned through the collimated structures which are visible outside the main body of the nebula. Note that these features are bright in the [N II] emission, fainter in Hα and invisible in He II. The velocity field is quite complex, showing an irregular shell-like expansion in the inner body of the nebula, and articulated structures with apparently low velocities (which, however, can be due to projection effects) in the collimated features. A detailed analysis of these data, coupled with low-resolution spectra to study the physical conditions and chemistry, will hopefully allow us to better understand the nature of these puzzling components of PNe, and shed new light on the very complex mass-loss phenomena which characterise the last stages of stellar evolution.

This was likely the first time that NTT+EMMI was used in this "high-dispersion long-slit" mode, and the results were indeed so good that we very much look forward to observing again with the same configuration, hopefully soon after the NTT Big Bang is completed. We conclude by warmly thanking Albert Zijlstra for the excellent support at the telescope and especially for encouraging us to try and use this "new" powerful capability of the NTT.

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